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INTERCRITICAL THERMOMECHANICAL TREATMENTS OF THE MICROALLOYED STEEL PRODUCTS FOR WELDED STRUCTURES

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ABSTRACT

This paper shows the laboratory experiments made on several grade steels by applying some intercritical thermomechanical treatments; Two variants were used: “down-up” thermomechanical treatment with heating and rolling in the intercritical range and “up-down” thermomechanical treatment with preliminary complete austenitizing and rolling in the intercritic interval. Structural changes, as well as changes of properties revealed in the experimental variants of the intrercritical treatment, have been compared to those revealed by controlled rolling and normalization states of delivery that are recommended to flat products from these steel grades. High values of the strength characteristics and a good plasticity have been obtained.

The paper presents only a part of the results obtained when applying different regimes of thermal and thermomechanical treatment within experimental researches made at laboratory and industrial scale, on thick plates of different thicknesses and qualities of the weldable steels.

KEYWORDS: termomechanical treatments, microalloyed steel, intercritical interval

1. Introduction

The literature recommends that the intercritical heat treatments should be applied to hypoeutectoide alloyed steels, underlining their positive effect on the plasticity characteristics and mainly on ductility characteristics. Nowadays researches show that the intercritical heat treatments can be successfully used in normalizing shipbuilding plates, in quenching some of the steel grades used in construction and in regeneration of the thermally influenced zone (TIZ) at welded joints of Ni-Mo-V low carbon steels as well as biphase steels. [1]

The purpose of unconventional thermal processing is to find alternative technological solutions to classical thermal processing, in order to obtain comparable using characteristics, but with economical advantages, such as: the decrement of energetic consumption and of metal losses by oxidation (the case of thermal treatments at low temperatures, which suppose intercritical heating of the hypoeutectoid steels) or the elimination of final thermal treatments (the case of the thermomechanical treatments that suppose the combination between plastic deformation and thermal treatment, (fig1).[2]

The paper presents some results concerning the influence of the intercritical thermomechanical treatment on the structure and the mechanical characteristics of microalloyed heavy steel plates.

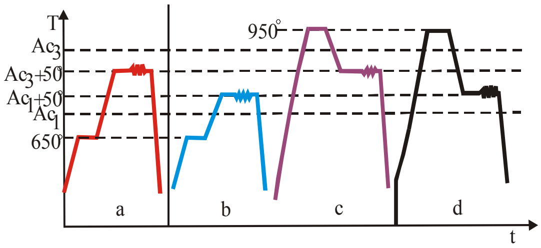

Fig. 1 *Technological variants for the intercritical thermomechanical treatment of the steel: a, b) "down-up" thermomechanical treatment; c,d) "up-down" thermomechanical treatment*

2. Experimental conditions

The research has been made on X60, X65 steels for welded pipes line.

The quality conditions in delivery state of the flat products are stipulated by European norms, Romanian standards.

In the title following tables are presented the chemical composition and mechanical characteristics imposed by the norms for the studied steels. (table no.1,2) [3]

Table 1. *Chemical composition of fine-grained, welded steels, for welded pipes (X60, X65)*

Steel Grade	C max	Mn max	P max	S max	Details
X 60	0,22	1,40	0,025	0,015	c, d
X 65	0,22	1,45	0,025	0,015	c, d

Note: (c) Nb,V,Ti or the combination between them is estabished by the producer.

(d) The Sum of the elements (Ni+V+Ti) must not exceed 0,15%

Table 2. *Mechanical properties according to API 5L/ 2004*

Grade steel	Rc, min [MPa]	Rm min [MPa]	A5 Min [%]
X 60	414	517	a
X 65	448	531	a

Note: (a) is determined through relations specified by the norm.

Table 3. *Chemical composition, [%]*

C	Mn	Si	P	S	Al	V	Nb
0,09-0,12	1,30-1,60	1,17-0,30	max. 0,025	max. 0,007	0,015-0,05	0,03-0,08	0,03-0,05

At Mittal Steel S.A. Galaţi, for the making of thick plates with the mentioned destination, the X65 steel qualities are elaborated, with the following chemical composition:

At Mittal Steel have been applied many classic thermal treatments regimes, that consisted in normalizations, hardenings and returns, and intercritical treatments consisting in normalizations and hardenings with returns in intercritical domains (fig.2).

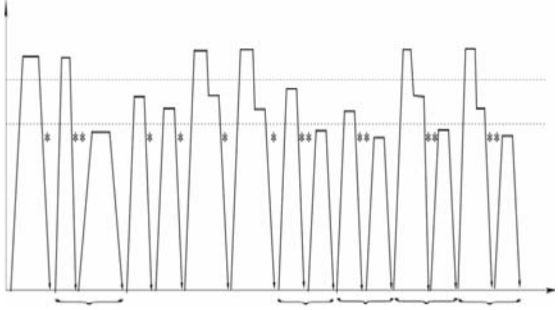

Fig. 2 *Experimental heating regimes*
** Air cooling ** Water cooling*

3. Experimental results

Furthermore, it is presented a part of the experimental results regarding the microstructural aspects and the values of physical and mechanical properties of the studied steels for certain experimental regimes of thermal treatments and intercritical thermomechanical treatments.

The following regimes have been applied:

A=normalizing

B= heating at 920^{o}C →cooling at 850^{o}C, rolling and cooling in water; ε =20% and 30%

C= heating at 920^{o}C →cooling at 850^{o}C, rolling→ air; ε =20% and 30%

D= heating at 920^{o}C→cooling at 800^{o}C+ rolling→ water

E= heating at 920^{o}C→cooling at 800 ^{o}C+ rolling→ air

F= heating at 850^{o}C→rolling→ water

G= heating at 850^{o}C→rolling→ air

H= heating at 800^{o}C→rolling→ water; ε =20% and 30%

I= heating at 800^{o}C→rolling→ air; ε =20% and 30% (ε - degree of rolling reduction)

In table 3 the mechanical properties obtained for the 13 regimes variants are presented:

Table 4. *Mechanical characteristics for the experimental regimes*

No.	Variants	Mechanical characteristics				
		ε [%]	Rm [N/mm^2]	Rp0,2 [N/mm^2]	A5 [%]	HB
1	A	-	546	368	29	278
2	B	30	804	764	22	292
3	C	30	637	579	29	191
4	D	30	803	753	20	285
5	E	30	577	412	26	174
6	F	20	834	685	32	292
7	G	20	686	566	26	202
8	H	30	1027	852	20	329
9	I	30	651	498	20	215
10	H	20	933	756	20	315
11	I	20	651	498	20	215
12	B	20	880	696	20	301
13	C	20	636	526	26	148

In figure 3 are presented the Rm and Rc values for the experimental regimes where the rolling deformation degree is ε =30%.

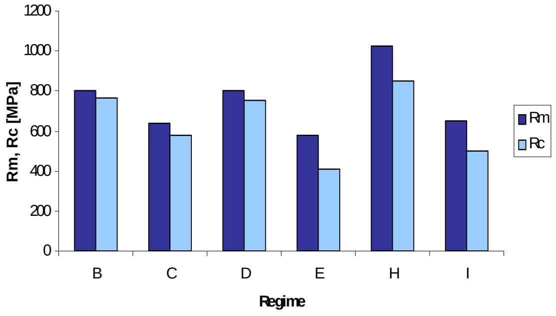

Fig.3 *Mechanical properties for some experimental regimes*

The following diagrams presents the laboratory experimental conditions at thermal and intercritical thermomechanical treatments.(fig.4)

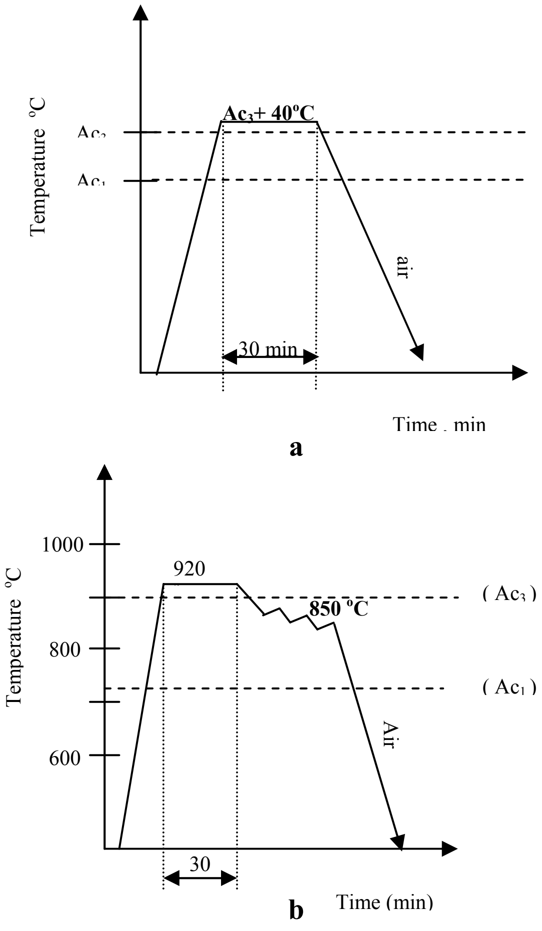

Fig.4 *Treatment cycles*
a – normalizing; b - intercritical thermomechanical treatment (C variant).

The followig pictures shows the microstructures that resulted after the applying of thermal and thermomechanical treatment regimes on steel X65.

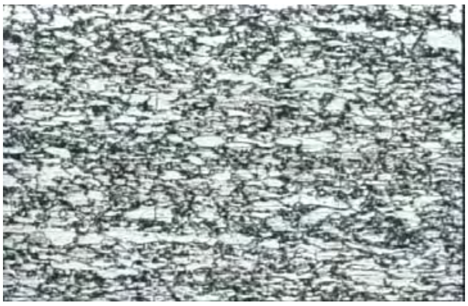

Fig. 5. *Diagram of normalization heat treatment - A variant (x500).*

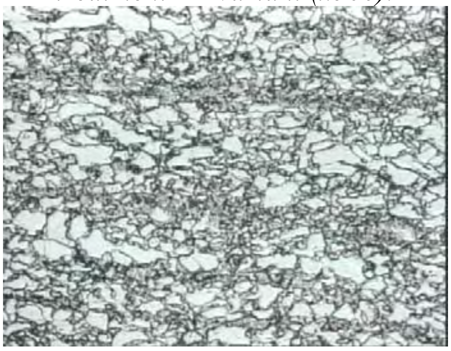

Fig.6. *Intercritical thermomechanical treatment state - B variant (x500).*

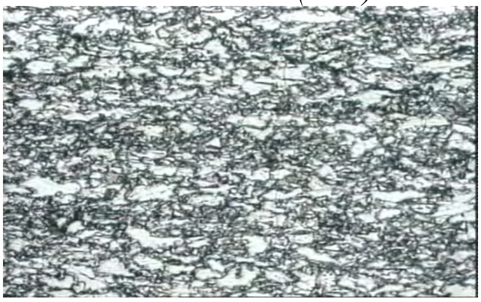

Fig.7. *Intercritical thermomechanical treatment state - C variant (x500).*

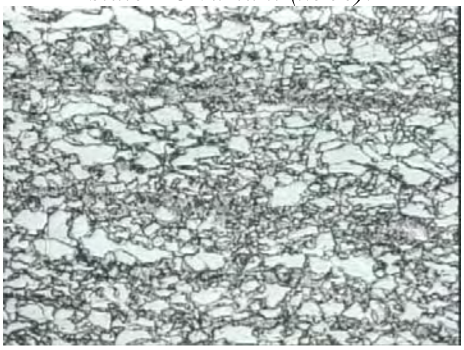

Fig. 8. *Intercritical thermomechanical treatment state - D variant (x500).*

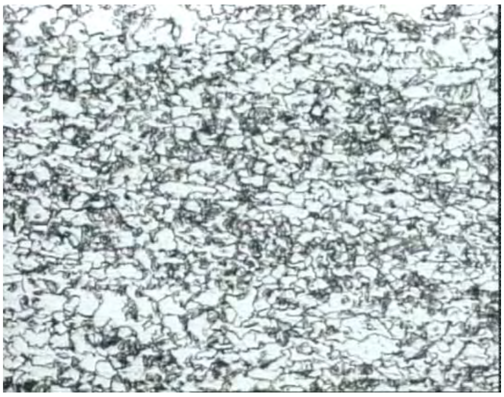

Fig.9. *Intercritical thermomechanical treatment state - G variant (x500).*

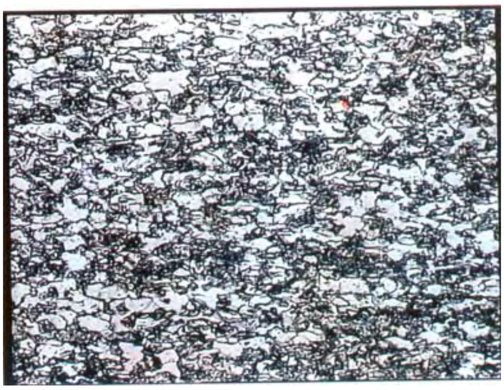

Fig.10. *Intercritical thermomechanical treatment state - I variant (x500).*

4. Conclusions

The laboratory experiments were made on several grade steels (X60, X65 for welded pipes) with same intercritical thermomechanical treatment application. According to present norms, the flat products made of the steel whose qualities have been characterized above, are delivered in normalized state or in equivalent state obtained by normalizing rolling (thermomechanical rolled steels).

Two variants were used: "down-up" thermomechanical treatment with heating and rolling in the intercritical range and "up-down" thermomechanical treatment with preliminary complete austenitizing and rolling in the intercritic interval. In this paper there are presented a part of the experimental results regarding the microstructural aspects and the mechanical properties values of the studied steels for certain experimental regimes of intercritical thermomechanical treatments.

Structural changes, as well as changes of properties revealed in the experimental variants of the intercritical treatment have been compared to those revealed by controlled rolling and normalization, states of delivery that are recommended to flat products from this steel grade.

For the X65 grade steel (with the chemical composition shown in table 3), for which the microstructural aspects for certain experimental regimes were presented in this paper, we can make up the following conclusions:

a) the air cooling, ("top to bottom" heating experimental variants) in opposition with water cooling, in all experimental variants, leads to the improvement of the plasticity properties, by maintaining their resistance mechanical properties, according to the norms;

b) the water cooling (all experimental variants) from intercritical interval, with 20 and 30% deformation stages, leads to very significant values of resistance properties (R_m= 636-1027 N/mm^2) while the plasticity properties drop (A_5= 20 –32%) the experimental variants with heating directly into intercritical interval ("bottom to top" variants, with no previous austenitizing), for deformation stages higher than 40%, independently from the cooling manner (air, water), lead to the achievement of an optimal complex of mechanical properties.

The analysis also reveals the fact that the main purpose of these experiments – namely to find a heat treatment variant able to efficiently replace the classical making process and of heat treating from the point of view of the energetic consumption, of the output costs and of the mechanical and properties – has been accomplished.

Thus, these mechanical characteristics of the flat rolled plates obtained by classical normalisation can be reached under optimal conditions by the intercritical thermomechanical treatments.

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